# APPENDIX B

# GEOTECHNOLOGY OF WASTE MANAGEMENT LANDFILL GAS MONITORING RESULTS LANDFILL NO. 4, PARCEL 81(5)

# Geotechnology of Waste Management

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Chapter 7

# Leachate and gas formation

## 7.1 Introduction

The waste in a sanitary landfill is a mixture of organic materials (e.g. garbage, paper, cardboard, textiles, plastic, wood, rubber) and inorganic waste, which may include metals such as cans and wires. As the refuse is placed in landfill, it undergoes oxidation and decomposition in the presence of oxygen, moisture and appropriate temperature. Water, which is essential for decomposition, is derived from the waste itself and is about 10–20% by volume or 100–200 $mm^3$ of water for each 1 $m^3$ of refuse (Fenn *et al.*, 1975). The rate of decomposition is influenced by type of refuse, ambient temperature, oxygen supply and water content. When infiltration exceeds the total evapotranspiration plus the moisture retention capacity of the refuse in the gravitational field, the water percolates through the refuse removing dissolved and/or suspended products of biological and chemical decomposition.

The biological degradation of the waste may occur in the presence of oxygen (aerobic bacteria), in an environment devoid of oxygen (anaerobic bacteria), or with very little oxygen (facultative anaerobic bacteria). Aerobic bacteria require oxygen to attack the organic material if the appropriate nutrients and moisture are present. Anaerobic bacteria remain mostly dormant in the presence of oxygen. Facultative anaerobic bacteria are adaptable to the presence of oxygen.

In all cases organic waste is broken down by enzymes produced by bacteria in a manner comparable to food digestion. Considerable heat is generated by these reactions with methane, carbon dioxide, and other gases as the by-products. A satisfactory design of landfill must consider measures for collecting and treating leachate, a leakage detection system, and gas ventings.

### 7.1.1 Aerobic decomposition

In the presence of oxygen, appropriate nutrients and moisture, aerobic bacteria usually generate water, carbon dioxide, organic acids and inorganic minerals. The major constituents of organic wastes in a sanitary landfill are foodstuffs, cellulose, and plastics, rubber and leather. Foodstuffs principally contain proteins, carbohydrates and fats. Materials containing cellulose include paper, rags, fruit skins, etc. Proteins consist of complex nitrogenous compounds and sulphur compounds that may be reduced to ammonia gas, nitric acid, sulphuric acid, carbon dioxide and water. Carbohydrates (sugar, starch) successively change to glucose, lactic acid and acetic acid, which finally oxidizes yielding carbon dioxide and water. Fats are split





into fatty acids and glycerine. Methane gas and carbon dioxide are the by-products of the oxidation of fatty acids.

Rubber and most plastics are usually resistant to biochemical degradation. Plastic polymers decompose into fragment molecules or monomers (Zerlaut and Stake, 1975) depending on their structure and conditions of heat, air, radiation, and mechanical methods used in manufacturing. Vinyl polymers such as polyethylene are resistant to monomer formation by virtue of their structure. Because of the high temperature associated with the aerobic phase some plastics may be altered.

The heat produced from aerobic decomposition elevates the initial temperature. Peak temperatures of 160°F (71°C) can be achieved in a few days to a few weeks after application of the cover (Noble, 1976). The high temperature (roughly 70°F (21°C) above ambient) may cause combustion of dry waste and generate fire.

### 7.1.2 Anaerobic decomposition

The consumption of nutrients and depletion of oxygen and moisture tend to inhibit the aerobic process and initiate the anaerobic decomposition process (Figure 7.1). In

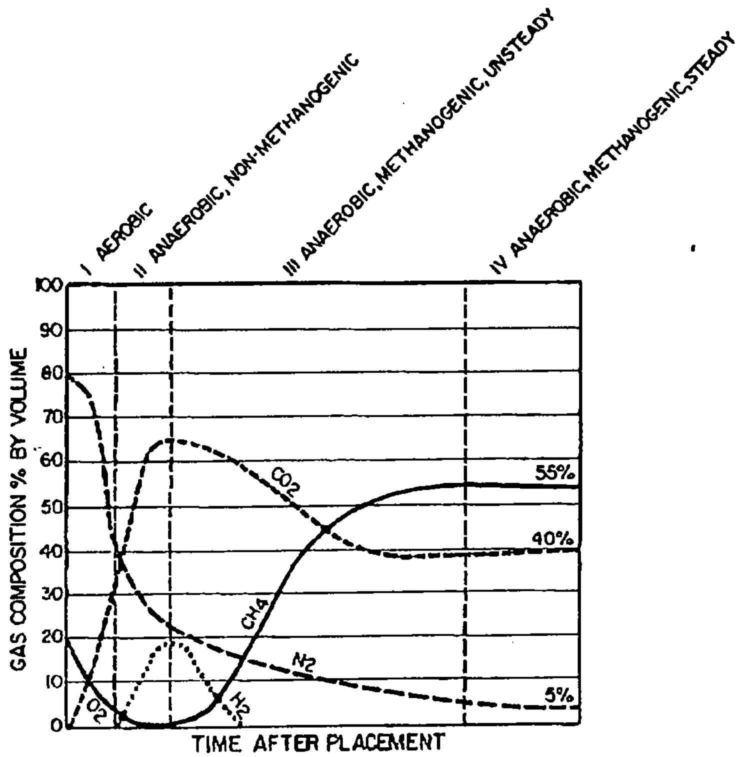



Figure 7.1 Gas composition and evolution in a typical landfill (Reproduced from Gas Generation Institute, 1981, by permission)

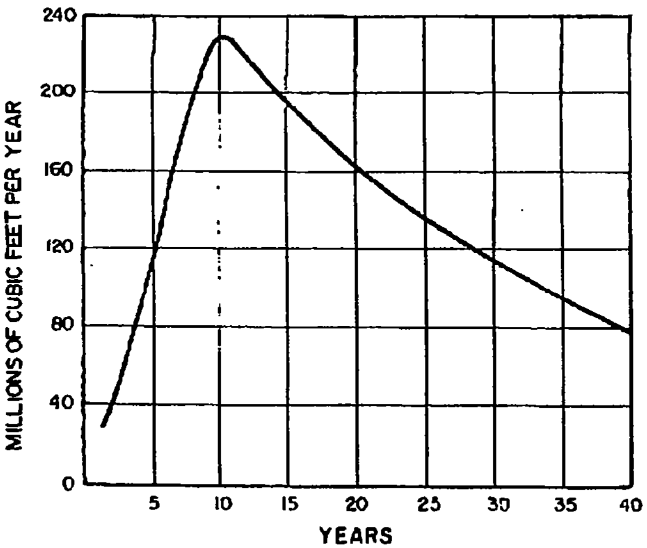



Figure 7.2 Typical gas generation profile for 1 million tons of solid waste (Reproduced from Gas Generation Institute, 1981, by permission)

the presence of moisture and appropriate nutrients, the anaerobic process and gas generation could extend over a long period after completion of the landfill as illustrated in Figure 7.2. Organic materials are broken down by facultative and anaerobic bacteria. In the initial phase of anaerobic decomposition the principal gas produced is carbon dioxide. With time, the amount of carbon dioxide decreases and methane increases, each reaching a plateau. The concentration of methane can reach 50–60%. A landfill may continue to produce methane at this rate for 10 or more years.

Carbohydrates and cellulose are converted into sugar then alcohol and various acids. Carbon dioxide is released and the pH drops, thus inhibiting the acid-forming process. The soluble acids are converted into methane and carbon dioxide. This raises the pH and the acid fermentation bacteria resume activity. The process would continue in the presence of nutrients, appropriate pH, temperature, and moisture. The heat generated by the anaerobic process is much less than that of the aerobic phase.

With the exception of metals, inorganic materials are not subject to corrosion. Metals are oxidized. Strong inorganic acids produced as by-products of decomposition could corrode metals. Chemical reactions could cause the galvanic action that accelerates the corrosion of metals. Plastics, glass and synthetic rubber remain essentially inert, and natural rubber breaks down extremely slowly.

## 7.2 Leachate

Leachate refers to the highly contaminated water that emanates from a disposal site.



The percolation of rainwater through a landfill or surface runoff from an ineffective landfill cover generates leachate. Leachate from a decomposing landfill usually contains various amounts of organic and inorganic chemicals. Tables 7.1 and 7.2 show the range of inorganic and organic constituents found in leachate from many landfills (Subtitle D Study, 1986). These chemicals and their concentrations impact the groundwater quality beneath and beyond the landfill. Table 7.3 illustrates the type of waste expected from various industries. Leachate generated from the disposal of hazardous waste may contain elevated amounts of heavy metals (e.g. mercury, lead), toxic substances (e.g. arsenic), and organic compounds. As illustrated in Tables 7.1 and 7.2 the concentrations of various organic and inorganic constituents vary. The leachate constituents significantly impact the design of the leachate containment and collection systems.

In the formation of leachate initially the solid waste particles and soluble materials are carried by percolating water. Later, the soluble components that enter the leachate stream are the result of complex series of biological and chemical reactions that generate both liquids and gases.

The constituents and character of the landfill affect the quality of the leachate (O'Leary and Tansel, 1986). An acidic pH condition increases the solubility of chemical constituents, decreases the sorptive capacity of refuse and increases the ion exchange between leachate and organic matter. Other parameters affecting the activity of leachate are the redox potential, adsorption, temperature and biological mechanism. The decomposition process could be inhibited by large changes of pH, unfavourable ionic concentrations and deficiency of nutrients (Lu *et al.*, 1985; Chen and Bowerman, 1975).

Table 7.1 Leachate constituents from municipal waste landfills

| *Constituent* | *Concentration* (mg/l) | *Constituent* | *Concentration* (mg/l) |
|---|---|---|---|
| Chemical oxygen demand | 50–90 000 | Hardness (as $CaCO_3$) | 0.1–36 000 |
| Biochemical oxygen demand | 5–75 000 | Total phosphorus | 0.1–150 |
| Total organic carbon | 50–45 000 | Organic phosphorus | 0.4–100 |
| Total solids | 1–75 000 | Nitrate nitrogen | 0.1–45 |
| Total dissolved solids | 725–55 000 | Phosphate (inorganic) | 0.4–150 |
| Total suspended solids | 10–45 000 | Ammonia nitrogen | 0.1–2000 |
| Volatile suspended solids | 20–750 | Organic nitrogen | 0.1–1000 |
| Total volatile solids | 90–50 000 | Total Kjeldahl nitrogen | 7–1970 |
| Fixed solids | 800–50 000 | Acidity | 2700–6000 |
| Alkalinity (as $CaCO_3$) | 0.1–20 350 | Turbidity (Jackson units) | 30–450 |
| Total coliform bacteria (c.f.u./100 ml) | 0–10 | Chlorine | 30–5000 |
| Iron | 200–5500 | pH (dimensionless) | 3.5–8.5 |
| Zinc | 0.6–220 | Sodium | 20–7600 |
| Sulphate | 25–500 | Copper | 0.1–9 |
| Sodium | 0.2–79 | Lead | 0.001–1.44 |
| Total volatile acid | 70–27 700 | Magnesium | 3–15 600 |
| Manganese | 0.6–41 | Potassium | 35–2300 |
| Faecal coliform bacteria (c.f.u./1000 ml) | 0–10 | Cadmium | 0.0.375 |
| Specific conductance (mho/cm) | 960–16 300 | Mercury | 0–0.16 |
| Ammonium nitrogen | 0–1106 | Selenium | 0–2.7 |
| | | Chromium | 0.02–18 |

Source: Subtitle D Study, 1986

**HGS Engineering, Inc.**
1707F Hillyer Robinson Industrial Pkwy South
Oxford, Alabama 36203
(256) 835-3800 • (256) 835-3301 Fax
ENGINEERING AND PROFESSIONAL SERVICES

April 25, 2001

Mr. Nolan Lee Jaye
Fort McClellan Transition Force
Bldg. 215, 15th Street
Fort McClellan, Alabama 36205-5000

Re: Methane Gas Monitoring

Dear Mr. Lee Jaye

Methane gas monitoring was performed at the Fort McClellan Landfill on April 12, 2001. S. Thornton of HGS Engineering accompanied T. Wardell and Chris Parker from ASI to the site.

The methane meter used for monitoring was a Digiflam 2000 flammable gas detector made by Neotronics. A Bar Hole Punch (4 ft. depth) was utilized when the gas well was inaccessible (i.e. casing caps could not be removed).

ASI practices immediate client notification and retesting of any wells with methane levels exceeding LEL (5% by volume).

There were no visible signs of GMP-22. Based on a map dated 7-13-94, a bar hole was made in the approximate location of the original site. The terrain prevented accessibility to GMP-12; a bar hole was made along the fence line within 25 feet of the original location.

The findings indicate one site registered methane; GMP-6 registered a 5% LEL and .25% volume.

Test results and site location map are attached. If we may be of any service, please call.

Sincerely

Sherryl J Thornton

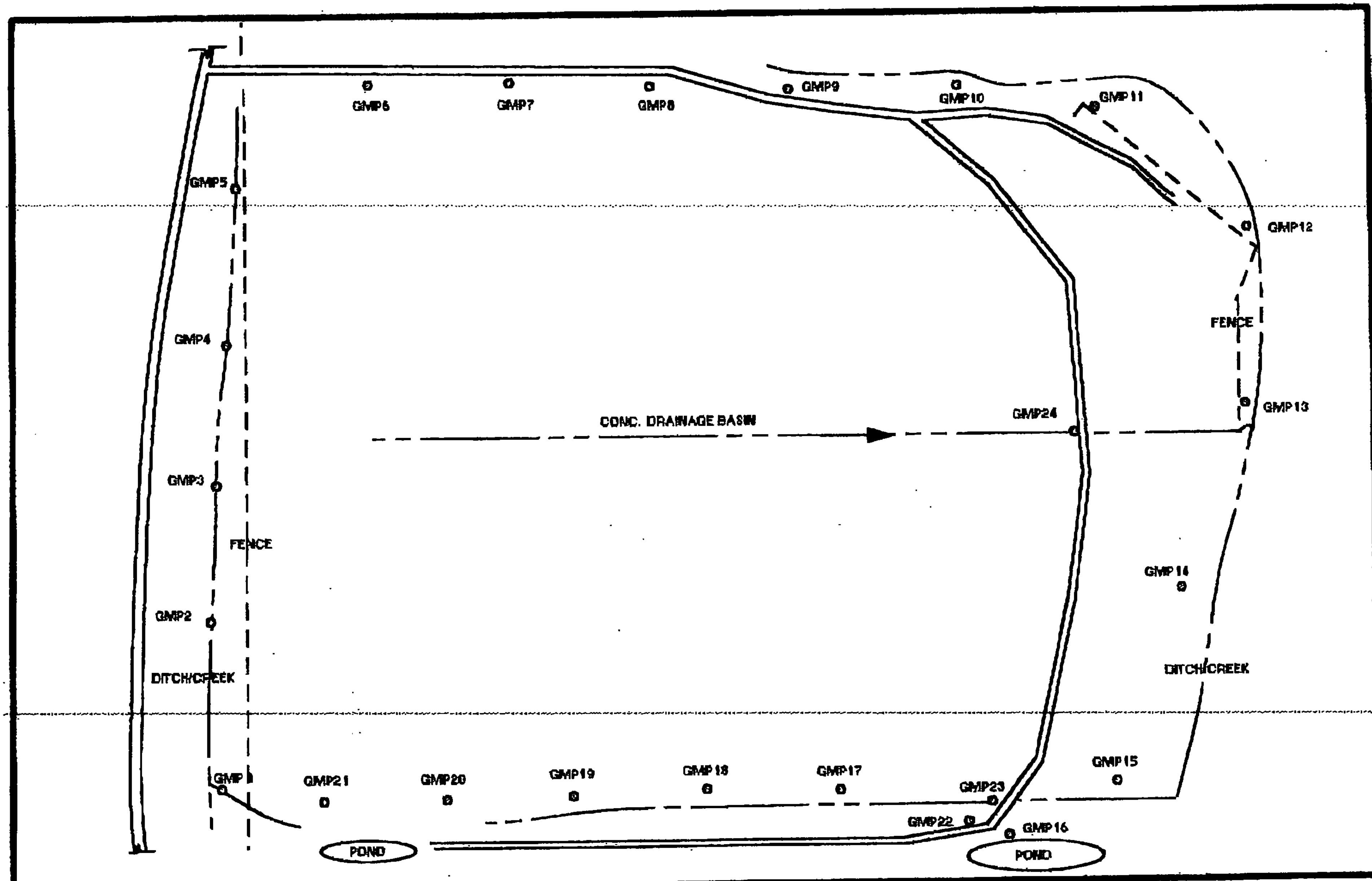
Sherryl J. Thornton, CEI

# FORT MCCLELLAN LANDFILL
# ANNUAL EXPLOSIVE GAS TEST RESULTS

| TEST RESULTS | | | DATE OF TEST: 04/12/01 |
|---|---|---|---|
| MONITORING POINT | PERCENT LEL | PERCENT VOLUME | REMARKS |
| GMP-1 | 0 | 0 | CULVERT |
| GMP-2 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-3 | 0 | 0 | CULVERT |
| GMP-4 | 0 | 0 | CULVERT |
| GMP-5 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-6 | 5 | 0.25 | BOREHOLE |
| GMP-7 | 0 | 0 | BOREHOLE |
| GMP-8 | 0 | 0 | BOREHOLE |
| GMP-9 | 0 | 0 | BOREHOLE |
| GMP-10 | 0 | 0 | BOREHOLE |
| GMP-11 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-12 | 0 | 0 | BAR HOLE PUNCH |
| GMP-13 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-14 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-15 | 0 | 0 | BOREHOLE |
| GMP-16 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-17 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-18 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-19 | 0 | 0 | BAR HOLE PUNCH* |
| GMP-20 | 0 | 0 | BAR HOLE PUNCH |
| GMP-21 | 0 | 0 | BAR HOLE PUNCH |
| GMP-22 | 0 | 0 | BAR HOLE PUNCH |
| GMP-23 | 0 | 0 | CULVERT |
| GMP-24 | 0 | 0 | CULVERT |
| | | | |
| | | | |
| | | | |

COMMENTS: * Bar hole punches were performed at these points. We were unable to remove the borehole casing caps. GMP-12 was inaccessible. A bar hole punch was performed along the fence line as close to the point as possible (within 25'). The culvert for GMP-22 no longer exists. A bar hole punch was performed at that point.

| | |
|---|---|
| TESTING BY: COMPANY: ANALYTICAL SERVICES, INC., NORCROSS, GA | EQUIP TYPE: DIGIFLAM 2000 |
| NAME: TRACY WARDELL, CHRIS PARKER | |
| SIGNATURE: Tracy Wardell | TEST METHOD: BAR HOLE PUNCH - 4' DEPTH |




| | | |
|---|---|---|
| April 12, 2001 | FORT MCCLELLAN LANDFILL | HGS Engineering, Inc.<br>(256) 835-3800 |
| HGS Rep: S. Thornton<br>ASI Rep: T. Wardell | ANNUAL EXPLOSIVE GAS MONITORING | FMCGASM/KC/SJT NTS |

# FORT McCLELLAN LANDFILL #4

# ANNUAL EXPLOSIVE GAS TEST RESULTS

| TEST RESULTS | | | DATE OF TEST: 5/30/00 |
|---|---|---|---|
| MONITORING POINT | % LEL | % VOLUME | REMARKS |
| GMP-1 | 000. | 00.0 | Culvert |
| GMP-2 | 020. | 01.0 | Borehole |
| GMP-3 | 000. | 00.0 | Culvert |
| GMP-4 | 000. | 00.0 | Culvert |
| GMP-5 | 008. | 00.4 | Borehole |
| GMP-6 | 016. | 00.8 | Borehole |
| GMP-7 | 042. | 02.4 | Borehole: swamp gas odor was evident |
| GMP-8 | 014. | 00.7 | Borehole |
| GMP-9 | 000. | 00.0 | Borehole |
| GMP-10 | 000. | 00.0 | Borehole |
| GMP-11 | 000. | 00.0 | Borehole |
| GMP-12 | 000. | 00.0 | Borehole |
| GMP-13 | 000. | 00.0 | Borehole: |
| GMP-14 | 000. | 00.0 | Borehole |
| GMP-15 | 000. | 00.0 | Borehole |
| GMP-16 | 000. | 00.0 | Borehole |
| GMP-17 | 000. | 00.0 | Borehole |
| GMP-18 | 000. | 00.0 | Borehole |
| GMP-19 | 000. | 00.0 | Borehole |
| GMP-20 | 000. | 00.0 | Borehole |
| GMP-21 | 000. | 00.0 | Borehole |
| GMP-22 | 000. | 00.0 | Culvert |
| GMP-23 | 000. | 00.0 | Culvert |
| GMP-24 | 000. | 00.0 | Culvert |

COMMENTS:

**TESTING BY: REISZ ENGINEERS**

NAME: Melissa Cannon / Stuart Johnson / Alvin Crawford

SIGNATURE: Melissa Cannon / Alvin Crawford / Stuart Johnson

EQUIPMENT TYPE: LANTEC GA 90

TEST METHOD: BAR HOLE PUNCH-4' DEPTH

[redacted]

| TEST RESULTS | | | DATE OF TEST: 7/8/99 |
|---|---|---|---|
| MONITORING POINT | % LEL | % VOLUME | REMARKS |
| GMP-1 | 0.0 | 0.00 | Culvert |
| GMP-2 | 8.0 | 0.40 | Borehole |
| GMP-3 | 0.0 | 0.00 | Culvert |
| GMP-4 | 0.0 | 0.00 | Culvert |
| GMP-5 | 0.0 | 0.00 | Borehole |
| GMP-6 | 0.0 | 0.00 | Borehole |
| GMP-7 | 0.0 | 0.00 | Borehole |
| GMP-8 | 0.0 | 0.00 | Borehole |
| GMP-9 | 0.0 | 0.00 | Borehole |
| GMP-10 | 0.0 | 0.00 | Borehole |
| GMP-11 | 0.0 | 0.00 | Borehole |
| GMP-12 | 0.0 | 0.00 | Borehole |
| GMP-13 | 0.0 | 0.00 | Borehole: swamp gas odor was evident |
| GMP-14 | 0.0 | 0.00 | Borehole: swamp gas odor was evident |
| GMP-15 | 0.0 | 0.00 | Borehole |
| GMP-16 | 0.0 | 0.00 | Borehole |
| GMP-17 | 0.0 | 0.00 | Borehole |
| GMP-18 | 0.0 | 0.00 | Borehole |
| GMP-19 | 0.0 | 0.00 | Borehole |
| GMP-20 | 0.0 | 0.00 | Borehole |
| GMP-21 | 0.0 | 0.00 | Borehole |
| GMP-22 | 0.0 | 0.00 | Culvert |
| GMP-23 | 0.0 | 0.00 | Culvert |
| GMP-24 | 0.0 | 0.00 | Culvert |

COMMENTS:

**TESTING BY: REISZ ENGINEERS**

NAME: Melissa Cannon / Ivan Zujevic
Alvin Crawford / Mike Rogers

SIGNATURE: Melissa Cannon / I. Zujovic

EQUIP TYPE: LANTEC GA 90

TEST METHOD: BAR HOLE PUNCH-4' DEPTH

| TEST RESULTS | | | DATE OF TEST: 6-9-98 |
|---|---|---|---|
| MONITORING POINT | % LEL | % VOLUME | REMARKS |
| GMP-1 | 0.0 | 0.0 | Culvert |
| GMP-2 | 1.0 | .2 | Borehole |
| GMP-3 | 0.0 | 0.0 | culvert |
| GMP-4 | 0.0 | 0.0 | Culvert |
| GMP-5 | 8.0 | 0.4 | Borehole |
| GMP-6 | 6.0 | 0.3 | " |
| GMP-7 | 0.0 | 0.0 | " |
| GMP-8 | 0.0 | 0.0 | " |
| GMP-9 | 0.0 | 0.0 | " |
| GMP-10 | 10.0 | 0.5 | " |
| GMP-11 | 0.0 | 0.0 | " |
| GMP-12 | 0.0 | 0.0 | " |
| GMP-13 | 0.0 | 0.0 | " |
| GMP-14 | 0.0 | 0.0 | " |
| GMP-15 | 0.0 | 0.0 | " |
| GMP-16 | 0.0 | 0.0 | " |
| GMP-17 | 0.0 | 0.0 | " |
| GMP-18 | 0.0 | 0.0 | " |
| GMP-19 | 0.0 | 0.0 | " |
| GMP-20 | 0.0 | 0.0 | " |
| GMP-21 | 0.0 | 0.0 | " |
| GMP-22 | 0.0 | 0.0 | culvert |
| GMP-23 | 0.0 | 0.0 | culvert |
| GMP-24 | 0.0 | 0.0 | culvert |

COMMENTS:

TESTING BY: REISZ ENGINEERING
NAME: Alvin Crawford / Larry Ratliff
SIGNATURE: Alvis B. Crawford / Larry Ratliff

EQUIP TYPE: LANTEC GA 90
TEST METHOD: BAR HOLE PUNCH-4' DEPTH

# REISZ ENGINEERING

3322 MEMORIAL PARKWAY S.
HUNTSVILLE, ALABAMA 35801
TELEPHONE (205) 883-2531

| TEST | RESULTS | | DATE OF TEST: ? 1997 |
|---|---|---|---|
| MONITORING POINT | PERCENT LEL | PERCENT VOLUME | REMARKS |
| GMP-1 | NDA | NDA | CULVERT |
| GMP-2 | NDA | NDA | BOREHOLE |
| GMP-3 | NDA | NDA | CULVERT |
| GMP-4 | NDA | NDA | CULVERT |
| GMP-5 | NDA | NDA | BOREHOLE |
| GMP-6 | 30 | 1.5 | BOREHOLE |
| GMP-7 | 158 | 7.9 | BOREHOLE |
| GMP-8 | NDA | NDA | BOREHOLE |
| GMP-9 | NDA | NDA | BOREHOLE |
| GMP-10 | NDA | NDA | BOREHOLE |
| GMP-11 | NDA | NDA | BOREHOLE |
| GMP-12 | NDA | NDA | BOREHOLE |
| GMP-13 | 26 | 1.3 | BOREHOLE |
| GMP-14 | NDA | NDA | BOREHOLE |
| GMP-15 | NDA | NDA | BOREHOLE |
| GMP-16 | NDA | NDA | BOREHOLE |
| GMP-17 | NDA | NDA | BOREHOLE |
| GMP-18 | NDA | NDA | BOREHOLE |
| GMP-19 | NDA | NDA | BOREHOLE |
| GMP-20 | NDA | NDA | BOREHOLE |
| GMP-21 | NDA | NDA | BOREHOLE |
| GMP-22 | NDA | NDA | CULVERT |
| GMP-23 | NDA | NDA | CULVERT |
| GMP-24 | NDA | NDA | CULVERT |
| Temporary Building | NDA | NDA | HE Industrial Waste Site' |
| Temporary Building | NDA | NDA | North Access Road |
| | | | |
| | | | |
| COMMENTS: | | | |
| TESTING BY: | EG&G, Inc. | | EQUIP. TYPE: LANTEC GA 90 |
| NAME: | Doug Johnson | | Multi-Gas Instrument |
| SIGNATURE: | Doug Johnson | | TEST METHOD: BAR HOLE PUNCH - 4' Depth |
| | | | |
| | | | |
| | | | |
| NDA - No detectable amount | | | |